

NSRP-SPC-SP1/3
PB 262 048

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MATERIALS HANDLING EQUIPMENT STUDY

VOLUME I

SUMMARY TECHNICAL REPORT

PREPARED BY:

INGALLS SHIPBUILDING DIVISION

OF

LITTON SYSTEMS, INCORPORATED

UNDER

CONTRACT 1-36200

FOR

THE OFFICE OF ADVANCED SHIP DEVELOPMENT

MARITIME ADMINISTRATION

WASHINGTON, DC 20235

Transportation
Research Institute

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE JAN 1974		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Materials Handling Equipment Study Volume 1 Summary Technical Report				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128-9500 MacArthur Blvd Bethesda, MD 20817-5700				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 33	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

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EXECUTIVE SUMMARY

This is a summary report of the Material Handling Study performed by Ingalls Shipbuilding Division under the provisions of Contract 1-36200 with the Maritime Administration. This report is composed of two volumes

Volume I contains a summary technical report documenting the results of the overall effort.

Volume II contains a series of appendixes, consisting of back-up technical data.

The objective of the study was to investigate material handling techniques and equipment currently used in United States shipyards and to determine methods of expediting and lowering the cost of the material handling function.

Specific projects were undertaken to develop new hardware and aids for improving material handling in shipyards. A brief description of the projects with their applicability to shipyards follows:

- a. Development of a multipallet transporter which has the ability to load, unload, and transport a minimum of three standard pallets weighing up to 12,000 pounds over ordinary shipyard roads.**

This transporter, demonstrated under shipyard conditions, proved to be an efficient and versatile piece of equipment for moving pallets around a shipyard.

b. Development of air lift platforms for movement of large structural units.

- (1) A 500-ton ship module air lift platform was developed and operated successfully on a specially prepared concrete surface with water as an operating medium.**

This platform will transport very heavy loads over specific routes on very smooth, specially prepared surfaces.

- (2) A 50-ton over-the-road air lift platform was developed and operated successfully on smooth sealed asphalt surfaces.**

This platform will transport loads over specific routes on sealed asphalt roads without significant discontinuities.

- (3) A 10-ton over-the-road air lift platform was developed and operated successfully on smooth asphalt surfaces.**

This platform will transport lighter loads over specific routes on asphalt roads without significant discontinuities.

- c. Development of the first comprehensive catalog of material handling equipment that is currently available and suitable for use in shipyards.**

This catalog has proved to be very helpful in defining the equipment that can be used to perform specific material handling functions.

- d. Development of a handbook which presents the economic options available for specific material movement tasks.**

The analytical results in the handbook should be a great assistance in developing the most economical methods for moving the various categories of material in a shipyard.

- e. An investigation of the material handling equipment in use in American shipyards.**

A successful demonstration of the equipment developed in this program was held at Ingalls for the shipbuilding industry.

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MATERIALS HANDLING EQUIPMENT STUDY

CONTRACT 1-36200

Section I

INTRODUCTION

1.0 INTRODUCTION

One of the major costs inherent in the shipbuilding industry is the movement of structural steel from point-to-point during the various stages of the construction process. Investigations of this area of the industry conducted under this contract revealed that methods, equipment, and techniques used by the older shipyards to transport structural steel generally have not been modernized or updated to keep pace with technological advances made during the past several years. Specific examples of the use of equipment embodying advanced technology used in newer shipyards are cited in paragraph 2.1.

A further complication in this area has been the growing trend in the industry toward modularized construction. As a result, in the final assembly stages, the loads to be moved, some of them over considerable distances, have greatly increased in size, weight, and complexity since World War II.

Since material movement equipment and techniques have not kept pace with advances in the construction processes, it has become necessary for material movement managers to accomplish the necessary movements by

improvisation, using equipment or combinations of equipments not designed to handle the increased loads.

This, in turn, has increased the costs of ship construction and has contributed to the ever-increasing decline in the percentage of the world shipbuilding performed in United States shipyards.

Because of these facts, a great need had developed for a thorough study of shipyard material handling techniques and equipment, for a compilation of the results of that study, and dissemination of the results to the various shipyards. From this study, it was believed that significant recommendations for improvements in material handling could be evolved, thus leading to decreased costs and, subsequently, to regaining a larger portion of the world shipbuilding program.

The material handling research and development effort was directed toward accomplishment of five major objectives.

a. Development of a versatile pallet handling vehicle with a self-contained capability of loading and transporting three pallets totaling 12,000 pounds over existing shipyard material movement routes at speeds up to 25 miles per hour.

b. Development of a use-tested air lift platform suitable for use in a shipyard environment to provide low cost transport of large, heavy assemblies from the point of fabrication to the erection or integration site. An additional facet of this objective was investigation of the feasibility of using an air bearing system in conjunction with a panel assembly line. This latter investigation was suspended after it was found that Todd Shipyards has successfully integrated such a system into their shipbuilding activities.

c. Development of a tabulation of design, specification and economic evaluation information on various methods of transporting large structural units currently used in shipyards. This objective also included an investigation of new transporting concepts used for large structural units (20-tons to multihundred ton range) which could lead to formulation of more cost effective shipbuilding practices.

d. Development of a reference catalog for shipyard management including a brief compilation of material handling equipment applicable to shipyard use and pertinent specification data. The resulting document would provide to shipyard movement managers the means to compare similar item: of equipment and select that which is better fitted for particular applications.

e. Development of a handbook with in-depth economic and descriptive information presented in such a manner that material movement personnel can, by a process of progressive analysis, select the most economical item of equipment to be used in specific material movement applications.

Ingalls representatives visited all the major American shipyards where they consulted local material handling personnel and observed material handling equipment and methods in operation (See Appendix B).

At the same time, visits were made to many of the major material handling equipment manufacturers to secure the latest information on equipment currently on the market.

Using the information obtained during the visits, personal experience, and an in-house Ingalls study as a basis a typical family of shipyard loads was definitized and a questionnaire (see Appendix C) was developed that was designed to elicit pertinent documented data regarding costs, percentage of use time, and overall utilization of material handling equipment.

The questionnaire was forwarded to major shipyards and equipment manufacturers (see Appendix C) with a request that the questionnaires be completed and returned to Ingalls for use in the R & D program. Response to the questionnaire was less than desirable, however, the results were compiled and are included in Appendix A.

Based upon the responses to the questionnaires, and upon the results of visits to shipyards, a procedure was set up to request proposals from material handling equipment manufacturers or other subcontractors, to evaluate these proposals, to fund and supervise new equipment development and manufacture, and to implement a demonstration of these equipments at Ingalls.

The demonstration occurred on October 17-19, 1973 at Ingalls, with representatives of MarAd and the marine construction industry present. The demonstration showed the versatility of the multi pallet transporter and the advantages and disadvantages of the air lift platforms.

In addition, Ingalls developed a Catalog of Material Handling Equipment and Handbook of Economic Options. This combined document was introduced at the demonstration and distributed to designated material handling personnel at a later date.

Section II

TRANSPORTATION OF LARGE STRUCTURAL UNITS

2.0 STUDY OF TRANSPORTATION OF LARGE STRUCTURAL UNITS.

2.1 SUMMARY. The survey, investigation, and observation of material movement equipment and techniques currently in use in United States shipyards revealed that there is little new or innovative in the approaches to material movement problems either in equipment or methods. One major exception to this generalization is employment of the air bearing concept in large scale movement operation at Todd shipyards.

This facility, is using this method to transport ship modules of several hundred tons from the fabrication area to the launch site. Inspired by the results of the Ingalls demonstration, the discussions with the manufacturers and conversations with the representatives of the many shipbuilding companies during the October meeting, Todd is now proceeding to broaden the air lift concept to a number of additional applications.

Another innovation in the handling of large structural units now in use is the ship translation system at Ingalls Shipbuilding. This system (see Appendix A) provides an automated method of moving ship modules to the integration area and the entire ship to the launching dock.

2.2 OBJECTIVE. The objective of the study of material movement equipment was to determine the equipment currently being used to move structural units from point-to-point during the ship construction process and to tabulate the data accumulated during the investigation.

A further objective of the study was to define ways and means by which material movement techniques could be modernized or improved to reduce material movement costs or facilitate operations and thus make United States shipyards more competitive in the world shipbuilding market.

2.3 APPROACH. Immediately upon initiation of the study an analysis was made of the types of large structural units which must be transported during normal shipbuilding operations. This analysis resulted in designation of eight basic loads, sketches of which are included in Appendix C.

A questionnaire was developed and dispatched to 10 participating shipyards (see Appendix C) requesting information on equipment in current use to transport the eight basic loads. Included in the requested information were operational costs and the type of equipment available in the shipyard to transport the selected loads. In addition, the questionnaire requested suggestions and recommendations on ways and means to reduce material handling costs and to facilitate movement.

Equipment vendors were also solicited regarding material movement currently available with special emphasis being placed on equipment that is new or represents an innovative approach to this field.

Individuals who had visited foreign shipyards were also queried about equipment being used in those installations for material handling purposes. Answers to such inquiries produced the information that much of the foreign equipment is similar to that produced in the United States and that some items have been purchased by American shipyards and are in daily use.

2.4 ANALYSIS. The data accumulated during the study and evaluation of the material movement field are tabulated and presented in Appendix A. Included in the material in the appendix are a tabulation of annual operating costs of representative equipment used in American shipyards, a study of pallet moving equipment, and a summarization of the equipment generally used to move larger assemblies in the shipyards.

2.5 CONCLUSIONS. The study of shipyard material handling equipment and methods revealed that there has been some significant improvements in these areas over the past several years. Among these improvements are the increase in size of hydraulic lift platforms and self-powering these units. This has resulted in expansion of the capability to move increasingly larger structural units from point-to-point during the construction process. This has been, and is being, accomplished, however, *in* the main, by improvisation using existing equipment and without taking full advantage in material handling technology.

Among the more recent innovations is the ship translation system (see appendix A) already in use in one shipyard. This system recently moved an entire ship from the construction area to a launching dock, the largest gross weight mass ever moved over land in a controlled operation.

Demonstrations and tests of air lift vehicles designed for over-the-road applications revealed that these vehicles are not suitable for use in existing ship yards and it is doubtful that these facilities could be modernized sufficiently to make such usage practical on a widespread basis. At the same time, the tests demonstrated that the use of such vehicles for specialized movement purposes over preselected, specially prepared routes presents an attractive opportunity for economical innovation. Lending enhancement to such usage is the fact that theoretically the load bearing capacity of such carriers is virtually unlimited, initial costs are low, and maintenance costs are minimal. Application of the air lift principle under such conditions has already been successfully employed by one shipyard to transport ship modules of several hundred tons from the fabrication area to the launch site and for positioning of an entire vehicle on the launchways. Another successful application of the air lift principle for shipyard use is a conveyor system transporting plate from storage to layout and cutting and forming shops.

Section III

AIRLIFT VEHICLES

3.0 STUDY OF AIRLIFT VEHICLES.

3.1 SUMMARY. Investigation of the use of the air lift principle in material movement equipment for transportation of large structural units in American shipyards on an over-the-road basis, proved that the use of such vehicles at the present time on a large scale is impractical.

The existing configuration of shipyard movement routes with exposed trackage, unsealed surfaces, inclines, and irregular surfaces effectively limit the flotation capabilities of such vehicles for shipyard use.

In newer shipyards, the use of this principle is feasible, however, on other bases if the facility has been designed to utilize the advantages of the principle. One shipyard is using the air lift platform concept "for positioning of entire vessels on the launchways." Another shipyard is also effectively using the air lift principle in a conveyor platform used for positioning plates before welding.

The unique features of air lift platforms, the low coefficient of friction, omnidirectional movement maneuverability, and relatively inexpensive initial costs suggest the strong possibility that these vehicles may be used successfully for other purposes in existing shipyards with only minor shipyard improvements.

One such use is as a station-to-station movement vehicle for assemblies requiring close tolerance fitting necessitating movement of the assemblies measured in small fractions of inches. Included in this use is as a movement medium for propellor, rudder, skag, and drive shaft jigs.

3.2 OBJECTIVE. The objective of this portion of the study was development of a practical air lift platform suitable for use in typical shipyard environments. The final product should be capable of low cost transfer of large, heavy assemblies from the fabrication area to the ship erection or module integration site. In addition, an investigation was to be made of the use of the air lift principle in panel assembly lines or conveyer lines.

A specific objective of this project was the production of a use-proven transporter suitable for transfer of large, heavy structural units from point-to-point over typical shipyard material movement routes.

3.3 APPROACH. The first step in completion of this project was compilation of a representative list of subcontractors knowledgeable in the area of air lift applications. Simultaneously, the Scope of Work and bid package were prepared for submission to prospective subcontractors.

Study of trade journals and reliance upon personal contacts produced a list of 26 firms which appeared to be sufficiently conversant with the air bearing principle to warrant solicitation for bids.

Letters of Inquiry were dispatched to each of the 26 firms, stating that Ingalls had a requirement for air lift platforms to meet certain requirements stipulated in the letter as a Scope of Work and requesting quotations based on the Scope of Work.

Of the 26 firms thus solicited only six indicated an interest in the project. One of these, Rolair, Inc., submitted quotations on two units, one of 50-ton capacity, the other of 500-ton.

The reasons advanced by Rolair for the submission of two bids require some explanation. The successful use of the air lift principle in material movement in other industries has been an established fact for *several* years. These uses, however, have been predicated upon specially prepared operating surfaces being available together with a central flotation medium.

Since the proposal requirements called for development of over-the-road vehicles capable of operating in existing environments, a bid was submitted for such a vehicle.

The second bid, that for the 500-ton unit, was submitted to cover development of an air lift platform which could operate in the existing shipyard environment if minor improvements were made to existing movement routes. Such improvements would include sealing of the operating surface, elimination of excessive grades, and elimination of railroad and crane trackage.

To perform a meaningful and impartial judgement of the replies to the Letters of Inquiry and bids, an Evaluation Board was established consisting of three Ingalls MarAd Project personnel and two invited members from other shipyards.

Using a prepared evaluation formula heavily weighted toward company background and the capability to produce the end product, each proposal was rated by each board member.

Each member's scoring was then tallied and successful bidders were selected on the basis of highest cumulative scores.

On this basis, it was decided Fansteel Special Structures and Air Barge Company, acting in conjunction, should be awarded a contract for a unit with 10-ton capacity and that Rolair Systems, Inc., be awarded contracts for a 50-ton unit and a 500-ton unit.

3.4 TESTS. Appendixes D, E, and F, covering the 10-ton, 50-ton, and 500-ton air lift platforms, respectively, include detailed descriptions of the vehicles developed under the provisions of Contract 1-36200, conditions under which vehicles were tested, and technical data accumulated during the tests.

3.5 CONCLUSIONS. Air lift vehicles, at the present state-of-the-art, are not sufficiently advanced for use as general purpose material handling equipment over existing routes in United States shipyards. Exposed rail and crane

trackage, inclined surfaces, compacted surfaced areas, and irregular cracked, and pot-holed road surfaces pose an insurmountable barrier unless major improvement of these routes is undertaken.

Motor driven fan/compressor combinations used to provide air pressure for air lift platforms must provide some means of noise suppression. The emitted noise levels of the units provided with the R & D platforms were unacceptable.

Omnidirectional movement is an inherent characteristic of air lift devices. To take advantage of this characteristic in positioning material in place in close tolerance situations would require a source of motive power. Positive directional control of the demonstrated air lift platforms was less than satisfactory and was primarily exercised along the longitudinal axis.

Existing air lift platforms will operate at design capacities when operating on specified surfaces as smooth concrete or sealed asphalt. Load bearing capacities diminish rapidly, however, as surface porosity increases and fail completely when the air source fails to provide the volume and pressure necessary to maintain levitation of the unit or when operating surfaces do not meet optimum conditions.

The use of water as a flotation medium would require further examination if projected for use under severe climatic conditions.

3.6 RECOMMENDATIONS. The following recommendations are made regarding the use of air lift platforms in American shipyards.

- a. That no more R & D funds be expended in an attempt to develop air lift platforms for use as an over-the-road material movement vehicles over the majority of surfaces presently existing in United States shipyards.
- b. That a continuing program be supported directed toward development of air lift platforms designed for station-to-station use in specified applications over specially prepared surfaces. Such applications would include, but not be limited to, movement vehicles for jigs supporting propellers, rudders, skags, tail shafts, and shaft hanger struts where close tolerances are a requirement and the omnidirectional movement characteristic of these units can be fully utilized. These are relatively light loads. From the results of this study, it would appear that very large loads (ship modules), can be similarly transported, again, over specially prepared surfaces.

Section IV
MULTIPALLET TRANSPORTER

4.0 STUDY OF MULTI PALLET TRANSPORTER

4.1 SUMMARY. Comments of material movement managers and operating personnel, supplemented by maintenance and usage records, indicate that the multipallet transporter will provide a tool which will fill a long-standing need in the shipbuilding industry. The speed and versatility of the vehicle will permit swift completion of tasks which formerly required costly, time-consuming additional operations. Extensive use under actual ship yard conditions showed that the basic design of the vehicle was sound and well-adapted to use on a day-to-day basis within the broad range of shipyard material movement activities.

4.2 OBJECTIVE. The objective of this project was the development of a pallet transporter that would be more versatile than transporters in use at the present time. We sought the design, development, and testing of a pallet transporter that would have the built-in capability of loading and transporting of three pallets weighing up 12,000 pounds. In addition, the vehicle should be adaptable to various materials and be capable of transporting the load over long distances at reasonably-high speeds (30 mph) over existing ship yard movement routes.

Thus the objective of this project was the development of a transporter to modernize pallet handling techniques and to provide a more versatile,

flexible and speedier means of handling palletized cargo than that afforded by the equipment now in use for that purpose.

4.3 APPROACH. Upon approval of the contract, an intensive survey was conducted of industries that appeared to either have the capabilities to produce a multipallet transporter of the desired type or were engaged in the production of forklifts or similar type handling equipment.

From this study, a list was compiled of thirty equipment manufacturers which were deemed potential participants in this project.

Requests for proposals incorporating the work scope were forwarded to each of the thirty firms.

Of these, four companies responded with proposals, 14 replied but declined to bid, and 12 did not answer.

Copies of the four proposals were forwarded to members of Panel SP-1 of the SNAME Ship Production Committee prior to the meeting of that body at Bath Iron Works on August 21, 1973. Each recipient was requested to review the proposals and be prepared to discuss them in detail at the meeting.

At the meeting, intensive discussion among attendees revealed that two of the proposals were nonresponsive to the intent of the program, and one

proposal was rejected because the bidder, while known for experience in material handling equipment, was not qualified in the transporter area.

The bid of Multi-Pallet Forklifts, Inc., was approved for two major reasons.

a. The quoted price was well within the budgetary allowance.

b. The transporter was already in production eliminating costly expenditures in design, development, and fabrication.

Following this action, and after MarAd approval of the selection, Multi-Pallet Fork Lifts was contacted and arrangements made to lease three of the vehicles for a minimum of two months.

For the tests of the vehicle under actual shipyard working conditions specified by the contract, it was decided to assign one vehicle each to Newport News Shipbuilding and Drydock, Todd Shipyards, and Ingalls Shipbuilding.

The planned schedule for usage was:

<u>User</u>	<u>No. Vehicles</u>	<u>From</u>	<u>To</u>
Todd Shipyard Los Angeles, CA	1	12 June	21 Sept.
Newport News Shipbuilding and Drydock, Newport News, VA	1	29 June	21 Sept.
Ingalls Shipbuilding Pascagoula, MS	1	15 May	19 Oct.

Tests of the vehicles were to consist of standard, day-to-day usage, within load limits, with the only restriction placed on the users being that a simplified usage sheet be maintained showing load weights, distances the loads were moved, and the number of pallets involved.

4.4 TESTS. A description of the multipallet transporter, the test conditions, and test results is given in Appendix G. Also included in the appendix are favorable and unfavorable comments pertaining to the overall design concept, recommendations for design modifications suggested as improving the capabilities of the vehicle, and a detailed maintenance record on the vehicle tested at Ingalls.

4.5 CONCLUSIONS. The multipallet transporter covered by this report is a tremendous advance in pallet handling equipment and is capable of fulfilling a long-standing need of American shipyards for a vehicle of this type with an over-the-road capability.

The vehicle possesses a high degree of versatility in pallet handling and maneuverability and is designed so as to permit transportation of long items through narrow doors and passageways, a task which cannot be performed by standard forklifts.

Comparison of the economics of moving pallets 1/4 mile or more by the multipallet transporter as opposed to equipment generally in use shows that the multipallet transporter is far superior.

Operators of this vehicle must be carefully chosen and well-indoctrinated in the capabilities of the transporter and precautions to be observed during operation.

4.6 RECOMMENDATIONS. It is recommended that the design of the vehicle be modified to conform with suggestions made in Appendix G to enhance the mechanical performance and decrease operating hazards.

It is further recommended that methods of handling material in a pallet be modified as necessary to incorporate the use of the multipallet transporter as the primary means of pallet movement except for very short moves and within buildings.

Section V
CATALOG AND HANDBOOK

5.0 DEVELOPMENT OF A CATALOG OF MATERIAL HANDLING
EQUIPMENT AND HANDBOOK OF ECONOMIC OPTIONS

5.1 SUMMARY

a. **CATALOG OF MATERIAL HANDLING EQUIPMENT.** The catalog in its present form, represents a tremendous advance toward compilation of data required by appropriate management personnel to make meaningful, objective decisions regarding purchase of material handling equipment and will prove to be an invaluable aid in making such decisions.

The catalog, at the publication date, was an up-to-date compendium applicable to the various types of equipment now in use, or considered adaptable for use, in shipyards. Experience has shown, however, that the publication will *soon* become obsolete, or outdated, unless changes and revisions to the document are made as required.

b. **HANDBOOK OF ECONOMIC OPTIONS.** The mathematical analysis of the various economic factors applicable to equipment available to perform day-to-day shipyard material movement tasks presented in this publication is the first definitive attempt to reduce the assessment of equipment requirements to a consideration of all pertinent requirement and economic factors. Even though the volume does not cover the solution to all such problems, it

is believed that sufficient information is presented to permit a meaningful analysis of such problems based on interpolation and extrapolation. Inclusion of blank computation pages, reproducible on a local basis, will permit material movement managers to compute solutions to such special problems.

5.2 OBJECTIVES The objective of this portion of the contract was the development of two publications, one delineating material handling equipment suitable for use in American shipyards and the other defining the economic advantages to be derived by using one piece of equipment for a specific task as opposed to some other.

a. Material Handling Equipment Catalog. This document should be compiled so as to present to affected personnel a virtually complete compendium of categorized material handling equipment currently available and tabulating physical characteristics, capabilities and costs of each item.

b. Handbook of Economic Options. The objective of this task was to provide to affected personnel a means of selecting the most economical equipment to be used for a particular material handling task on an analytical basis. To do this, the publication should present tabular data pertinent to all factors that would affect such a decision and list equipment suitable for the task with comparative costs for each item of equipment.

5.3 APPROACH Upon acceptance of the technical proposal by MarAd, an intensive survey was made of material movement equipment currently available. This included a comprehensive review of equipment lists, trade journals, material handling industry magazines and specification sheets and contacts with manufacturers.

Material movement equipment was divided into eight general classifications, seven of which are as established by the International Material Management Society, the other an arbitrary classification to cover equipment not properly falling into any of the established categories. The classifications used for this project were:

- a. Conveyors
- b. Cranes
- c. Industrial vehicles
- d. Motor vehicles
- e. Railroad cars
- f. Marine vehicles
- g. Containers and supports
- h. Miscellaneous.

Standardized data collection sheets were then devised for each classification to ensure uniformity of data for inclusion in the volumes. Letters were dispatched to over 380 equipment manufacturers requesting that each complete data sheets applicable to the firm's products.

While the majority of responses to the requests were in the form of brochures, enough data was collected to provide a comprehensive coverage of the material handling equipment field.

Once sufficient data had been accumulated, Ingalls MarAd Program personnel initiated a survey to determine firms in the publications field that were experienced in the preparation of publications similar to that required by the contract.

After completion of the bid package, requests for proposals were submitted to seven contractors. Four of the firms responded with bids, two requested additional discussion to reduce the scope of work and one did not reply.

The proposal evaluation board, composed of three Ingalls representatives and two invited members of other shipyards, evaluated each proposal using a weighted scoring formula and compilation of the scoring showed that the proposal submitted by Equipment Guide Books, a recognized authority in the publications area, best fitted the requirements of the contract.

Compilation of the two volumes started immediately using information and data previously compiled by Ingalls supplemented by that already in the subcontractor's files, plus information supplied by vendors.

At this point, efforts in this area proceeded in dual directions, one designed to produce the equipment catalog, the other to produce the handbook of economic options.

a. Catalog of Material Movement Equipment. The format chosen for this volume was similar to that employed by the subcontractor in preparing a similar volume for the construction industry. One item of the particular class was illustrated as an example and other equipment of the same general classification was tabulated giving the manufacturer's name, physical characteristics, costs, and capabilities.

b. Handbook of Economic Options. This volume, an innovation in the industrial world, was evolved primarily from basic data compiled by Ingalls during the study of transportation of large structural loads (See Volume II and Appendix A.) To derive the formular approach, equipment was broken down into classifications that possess the capability to perform tasks determined by the earlier analysis to be representative of daily shipyard requirements.

Next, all economic considerations bearing upon the use of a particular item of equipment for a specified task were analyzed and compiled and fitted into the selection formula. Finally, the comparative costs of using each item of equipment were computed, giving the reader instant access to the most economical equipment to be used for the task.

Close coordination was maintained with subcontractor personnel during the preparation of both volumes, especially during involvement of the handbook of economic options. Ingalls representatives made numerous trips to the subcontractor's facilities and telephone consultations were held frequently.

5.4 CONCLUSIONS The conclusions reached as a result of the Ingalls review of the Catalog of Material Handling Equipment and the Handbook of Economic Options and the comments of recipients of the documents are presented below.

a. Catalog of Material Handling Equipment.

(1) The material presented in this volume has been prepared so as to include sufficient detail to permit a meaningful comparison of various items of equipment when initial purchase or replacement is contemplated.

(2) The equipment has been classified in accordance with the categories originally established by the International Material Management Society and the American Society of Mechanical Engineers.

(3) While the data presented in the catalog was as complete and up-to-date as possible at the time of publication, experience has shown that such data rapidly becomes obsolete unless a program of updating and revision is instituted and maintained.

(4) The loose-leaf binding of the document would facilitate updating and revision.

b. Handbook of Economic Options.

(1) The analytical approach to the solution of material movement problems presented in this volume is logically conceived, includes all the pertinent details required to define the problem accurately and lead the user to the optimum solution of the problem in question.

(2) Instructions for use of the volume are complete and concise.

(3) Inclusion of blank analysis pages, suitable for local reproduction, will provide a convenient tool for material movement management in resolving problems not specifically covered in the handbook.

5.5 RECOMMENDATIONS The following are the Ingalls recommendations pertaining to the catalog/handbook covered in this report.

a. It is recommended that the catalog/handbook be accepted for use by domestic shipyards as a basis for determination of budgetary requirements for new material handling equipment.

b. It is also recommended that this catalog/handbook be given the most intensive usage by all shipyard personnel engaged in the cycle of evaluation and recommendation of material handling equipment.